Approach Navigation Challenges For Mars Sample Return

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Extended Abstract

The main objective of the MSR mission is to collect a sample of Martian rock and soil and to send that sample back to Earth for analysis. The current architecture for this mission as it stands today consists of three mission elements, two landers to be launched in 2003 and 2005 along with an orbiter in 2005. The landers' objectives are to collect samples of rock and soil using landed systems and rover systems. Then the lander must transfer the samples to the Mars Ascent Vehicle upon which time they will be launched into orbit. The joint JPL/CNES orbiter will then attempt to rendezvous with the orbiting samples and return those samples to Earth. Additionally the orbiter is scheduled to deliver science probes called Netlanders to the Martian surface during its Mars approach phase. In order to accomplish these mission objectives a number a navigation challenges must be met. These challenges include accurate targeting/delivery of two precision landing spacecraft, targeting/delivery of 4 Netlander probes, accurate targeting/delivery of the orbiter for aerocapture, orbiter and sample rendezvous, and accurately delivering the sample and spacecraft back to Earth. The purpose of this paper is to highlight the challenges posed by accurately delivering each spacecraft to its atmospheric entry interface point at Mars. The problem of Mars orbit rendezvous and Earth return navigation will not be discussed.

Each spacecraft delivery has unique issues determined by the required delivery accuracy, the interplanetary trajectory, and the spacecraft operating characteristics. The results presented in this paper are a snapshot of the work to date that was completed in order to understand the unique issues of each spacecraft's Mars approach phase and atmospheric entry delivery. The delivery of the 2003 lander has the characteristic of travelling on a type I trajectory and therefore has a favorable Mars/Earth geometry. The 2005 lander is scheduled for a type II trajectory and the delivery accuracy is hindered by the Mars/Earth geometry. This can be seen in figure 1a and 1b which plot the orbit knowledge of the 03 and 05 landers as a function of time until Mars entry where all orbit determination assumptions are the same except the trajectories. The spike in the orbit knowledge at entry minus ten days corresponds to a trajectory control maneuver and subsequent execution error.

The delivery of the Netlander probes is unique because it introduces the problem of delivering four spacecraft to four different entry targets. The goal here is for the orbiter to perform the maneuvers to target each probe, then release each probe on its entry trajectory. This method of targeting and deploying starts approximately 30 days before entry with a target and release sequence occurring every four days. After the Netlander probes are released the orbiter is targeted to the aerocapture entry point. The main challenge involved with this strategy is to set the targets and the target maneuver schedule in order to minimize the ΔV and minimize the time for errors to propagate to the entry interface. Figures 2a and 2b show the degradation of the orbit determination knowledge due to maneuvers execution errors introduced by each Netlander probe targeting maneuver.

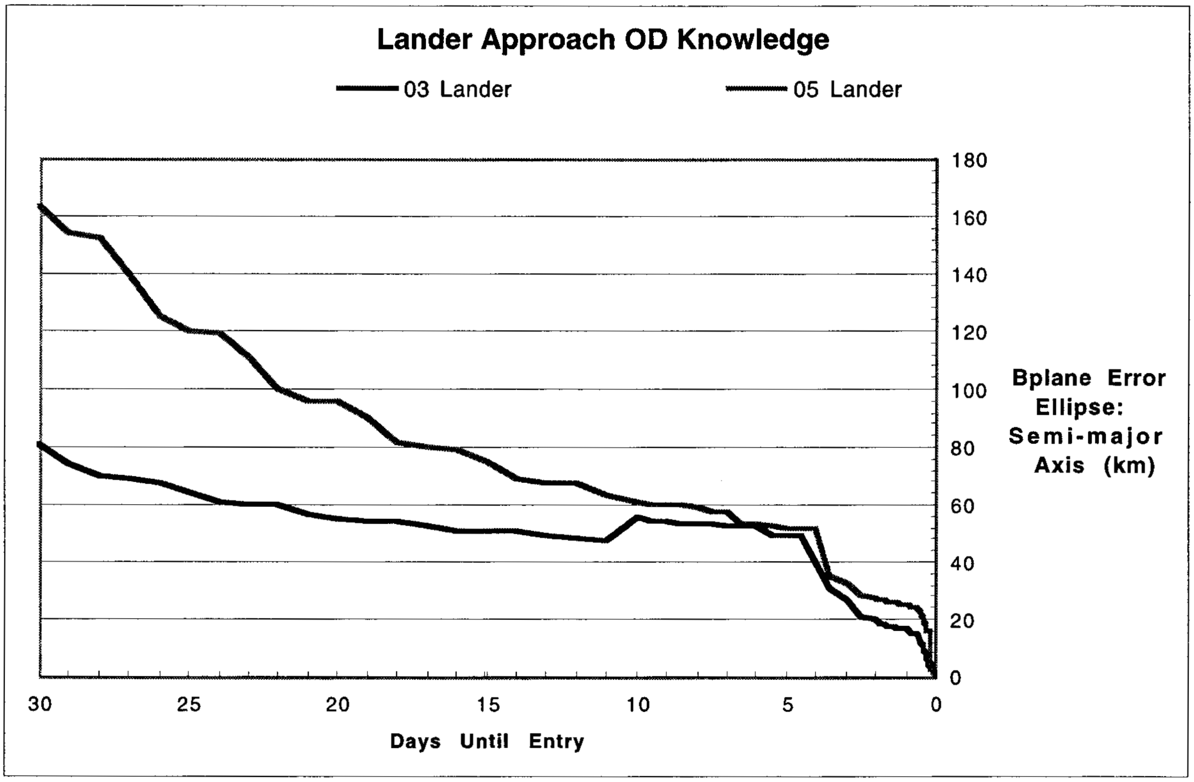

Figure 1a : Lander Approach Orbit Determination Knowledge:
a: Semi-major axis of Bplane error ellipse vs Time

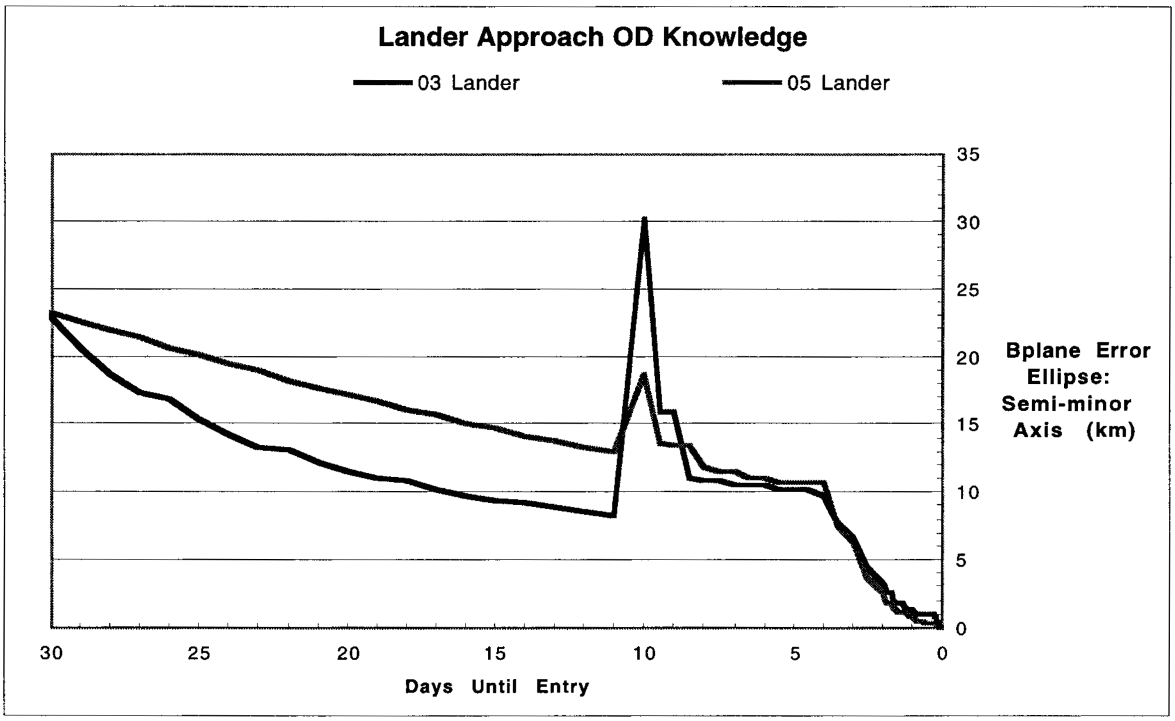

Figure 1b: Lander Approach Orbit Determination Knowledge:
b: Semi-minor axis of Bplane error ellipse vs Time

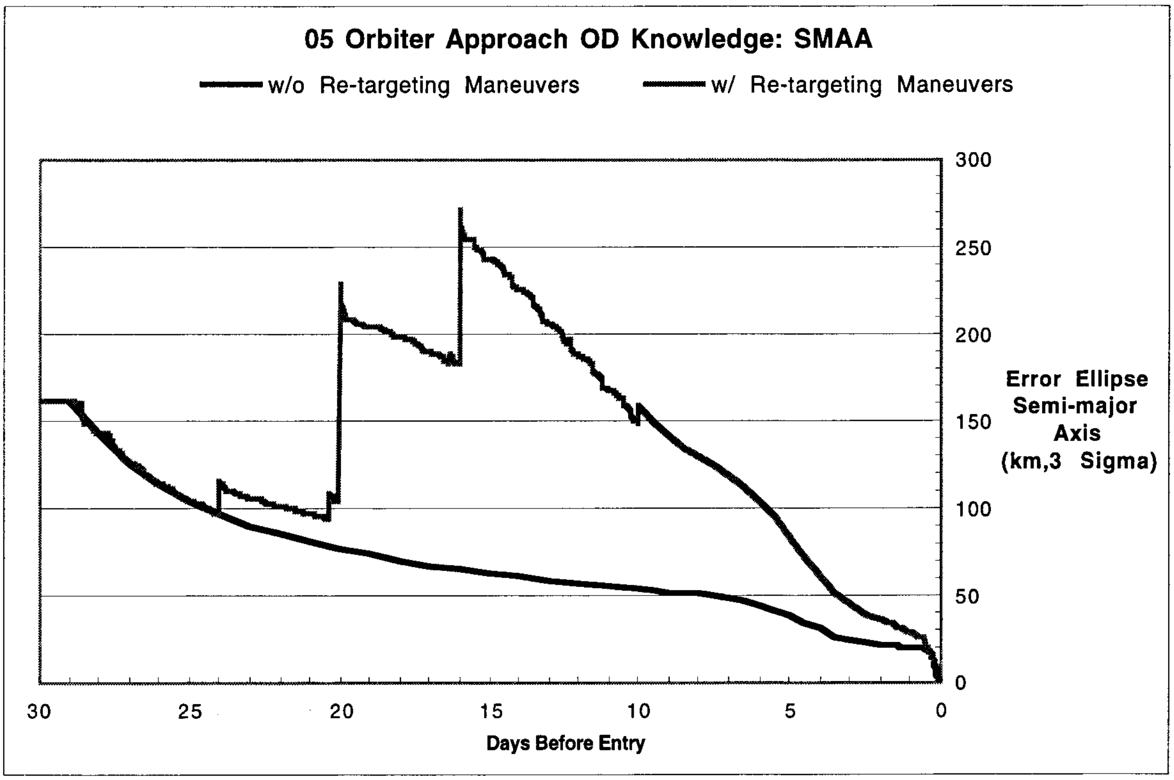

Figure 2a: 05 Orbiter Approach Orbit Determination Knowledge
a: Semi-major axis of Bplane error ellipse vs Time

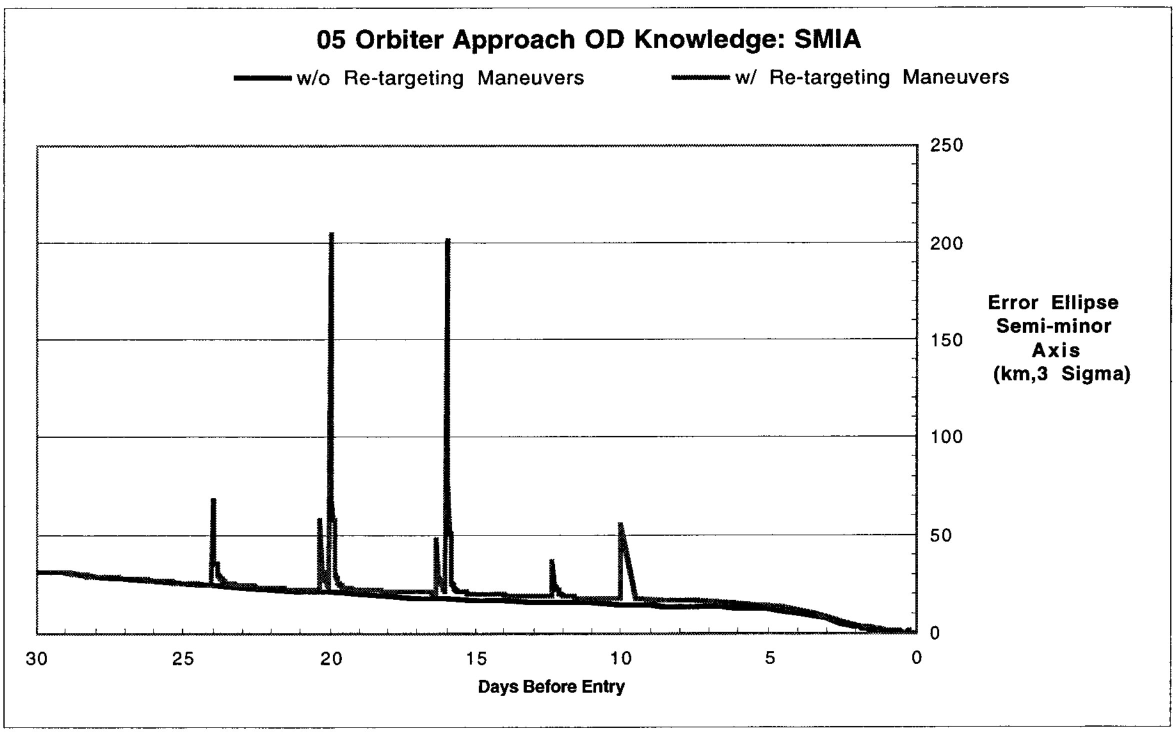

Figure 2b: 05 Orbiter Approach Orbit Determination Knowledge
b: Semi-minor axis of Bplane error ellipse vs Time

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